Senior Thesis

EFFECTS OF RECLAMATION ON SEDIMENTATION AND WATER QUALITY OF THE WEST BRANCH SHADE RIVER

by
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ABSTRACT

From the mid-1940s until the early 1960s, coal was extensively strip mined in southeastern Ohio. Due to poor reclamation efforts, the West Branch Shade River has been exposed to a high accumulation of sediments. The result of this accumulation is a loss in channel conveyance. This increased sedimentation caused more frequent, and larger scale flooding, which raised considerable concern for local residents. In October 1994, measurements were taken from two areas of study to help provide information of the effectiveness of reclamation. A comparison to a similar study completed between October 1983, and September 1984 will be used as a control.

The water quality of the West Branch Shade River was found to have a pH level from 6.1 at station 1 to a level of 4.9 at station 2. Specific conductance ranged from 435 microohm per centimeter at station 1 to 565 microohm per centimeter at station 2. Sediment thickness on the stream bottom ranged from 1.8 centimeters to 25 centimeters. A concentration of coal fragments was evident in the stream.

INTRODUCTION

The West Branch Shade River is located in Northern Meigs county just south of Athens, Ohio (figure 1)(Childress and Jones, 1985, p.3). Due to a deposition of sediment, there has been a decrease in channel conveyance. A decrease in channel conveyance has a direct effect on flooding in the area. The increase in

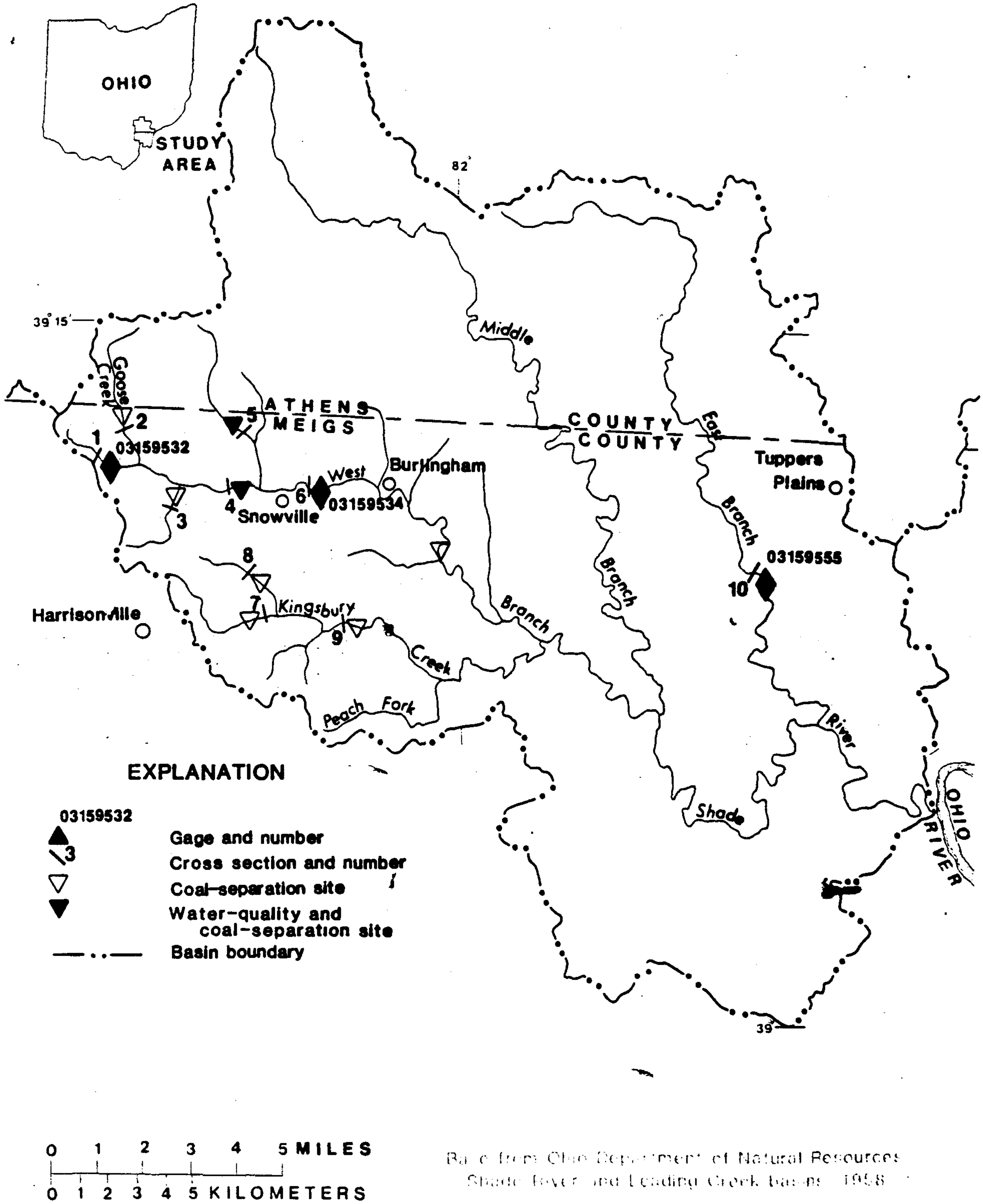

Figure 1. Location of the West Branch Shade River. (from Childress and Jones, 1985)

flooding raised a considerable amount of concern for area residents and officials.

The area under study was surface mined for coal from the mid- 1940s until the early 1960s. The coal that was mined was overlain by the Pomeroy Sandstone. The mining companies removed the Pomeroy Sandstone, to get to the coal, and discarded the sandstone into spoil piles. The piles were located at the head-waters of the West Branch Shade River. Although law required the reclamation of these spoil piles, reclamation did not have to prove successful, and many areas were overlooked. The spoil piles provided a sediment source that contributed to sediment loading and poor water quality in the watershed (J. Havasi, 1994, peers. comm).

Due to environmental concerns, the headwaters of the West Branch Shade River were reclaimed under the new surface mining act (PL 95-87). Reclamation efforts took place from 1978 to 1984. A test of sedimentation and water quality was conducted from October 1983, until September 1984, by the U.S. Geological Survey (Childress and Jones, 1985). The results of this study are available in an open file report <u>Sedimentation and Water Quality in the West Branch Shade River Basin, Ohio, 1984 Water Year.</u>

PURPOSE AND SCOPE

The reason for reclamation of the headwaters of the West Branch Shade River was to reduce stream sedimentation, and control the acid-drainage problem. The purpose of this report is to analyze the effectiveness of reclamation with a portion of the West Branch Shade River. To meet this objective, data from the 1984 report were compared with data that I collected in 1994. Information was gathered from two measuring stations located near the headwaters, and further down stream (figure 2). Specific conductance at each station was obtained by the use of a conductivity meter; pH was obtained by the use of litmus paper. Physical characteristics in the fluvial system were recorded using a transit, a Jacob's staff, and a tape measure. The depth of the sediment in the river bed was obtained by the use of a one meter clear tube. Also, observations on the channel sinuosity and landforms were noted.

DESCRIPTION OF STUDY AREA

The West Branch Shade River runs through the towns of Burlingham and Snowville, in Meigs county, just south of Athens county (figure 1). The area of study was a part of the major coal producing section of Ohio. The weather in southeastern Ohio can be described as extremes of humidity and temperature. Mean daily temperatures range from -2.2 and 32.2 degrees Celsius (Pfaff et al, 1981, p.4). The annual precipitation averages 102 cm a year and is generally greatest in the spring and least in the autumn (Pfaff et al., 1981, p.4). Southeast Ohio is a predominantly rural area with its major land use being farming.

The coals that are found in Ohio lie in strata of Permian and Pennsylvanian age. These strata represent a fluvial deltaic depositional environment and are characteristic of an alternating

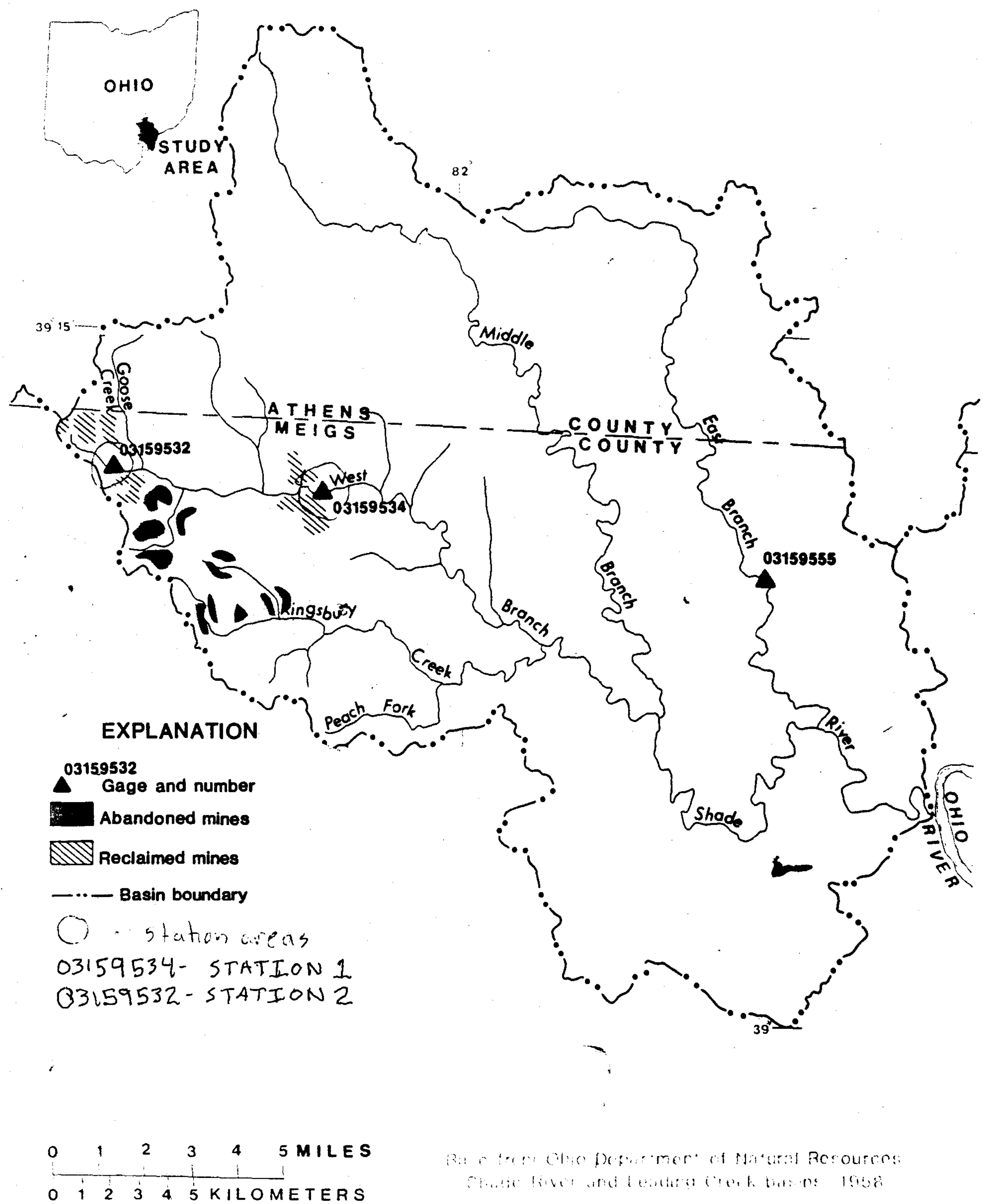

Figure 2. Location of the Measuring Stations.(from Childress and Jones, 1985)

sandstone, shale, mudstone, coal, and marine, brackish, and freshwater limestone (Pfaff et al, 1981, p.5). The Cincinnati Arch caused the Pennsylvanian and Permian formations to crop out in northeast-southwest-trending bands (figure 3) and to dip 25 to 1.4 meters per Kilometer southeast (Pfaff et al, 1981, p.5).

Fifty-two coal beds are recognized in Ohio. Most of the coal beds in Ohio are discontinuous, thin, and of poor quality. Mining has traditionally concentrated on the numbered coals (Sharon No. 1 through Waynesburg No. 11)(Figure 4), and supplied most of the coal mined in Ohio (Pfaff et al, 1981, p.5). The coal deposits that were mined in the West Branch Shade River valley are the Pittsburgh No. 8 and the Redstone coal No. 8a (figure 4).

Driving through The West Branch Shade River valley, high walls were observed showing evidence of past strip mining. Approximately 450 acres of abandoned surface mines had been reclaimed in the West Branch Shade River basin by the end of 1984 (Childress and Jones, 1985, p.2).

BACKGROUND

Coal has been mined in Ohio since 1804 (Pfaff et al, 1981, p.2). At first the mines were small operations, but as the demand for coal increased, new technology was needed to remove the coal at a faster rate. Equipment and techniques were developed to utilize a concept called strip mining. One of the main problems that arose from strip mining was acid drainage from the exposed mines. Until 1948, no laws requiring reclamation

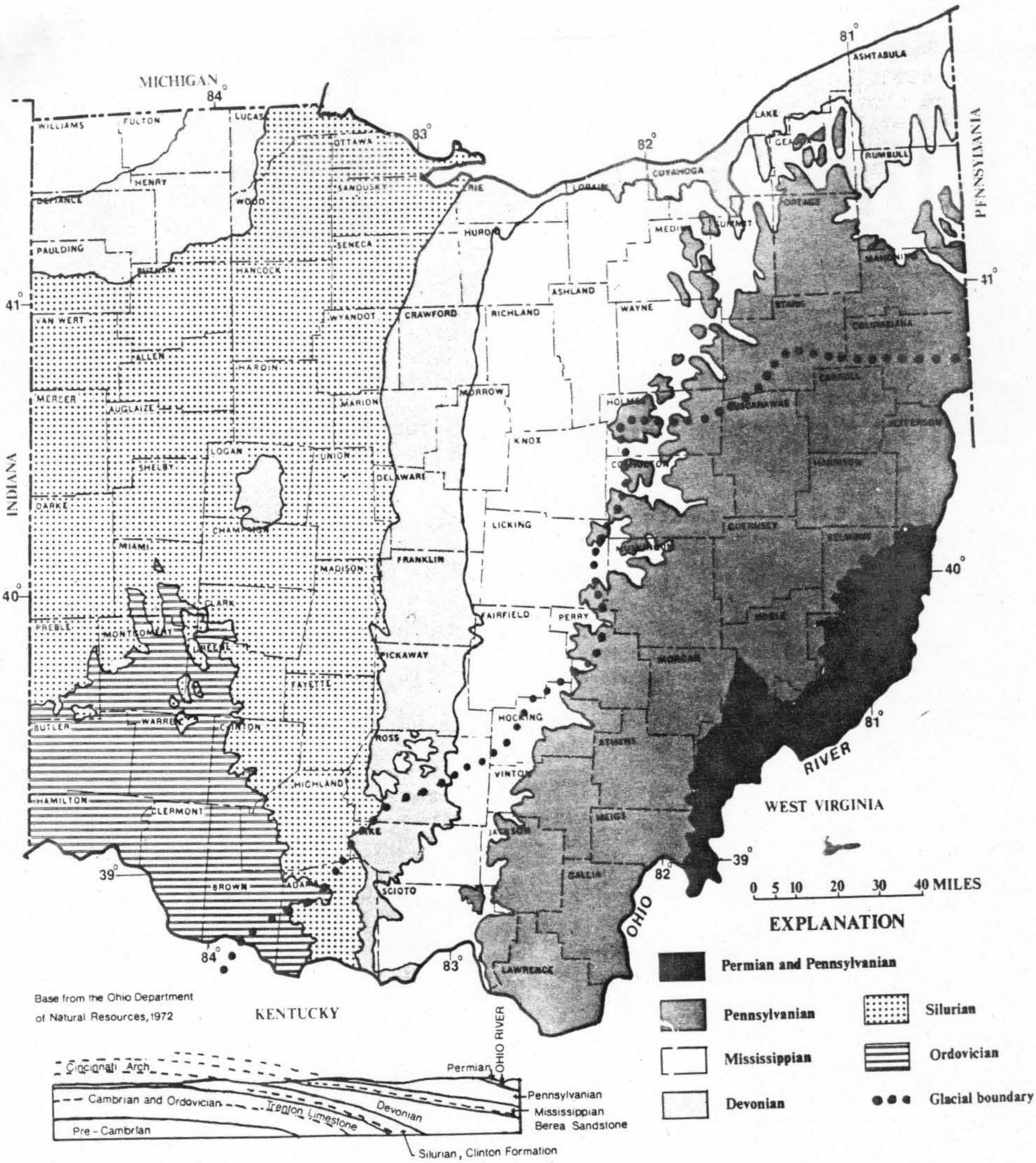

Figure 3.--Geologic map of Ohio, showing location of formation outcrops and glacial boundary; geologic section, showing the Cincinnati arch, (modified from Ohio Department of Natural Resources, Division of Geological Survey).

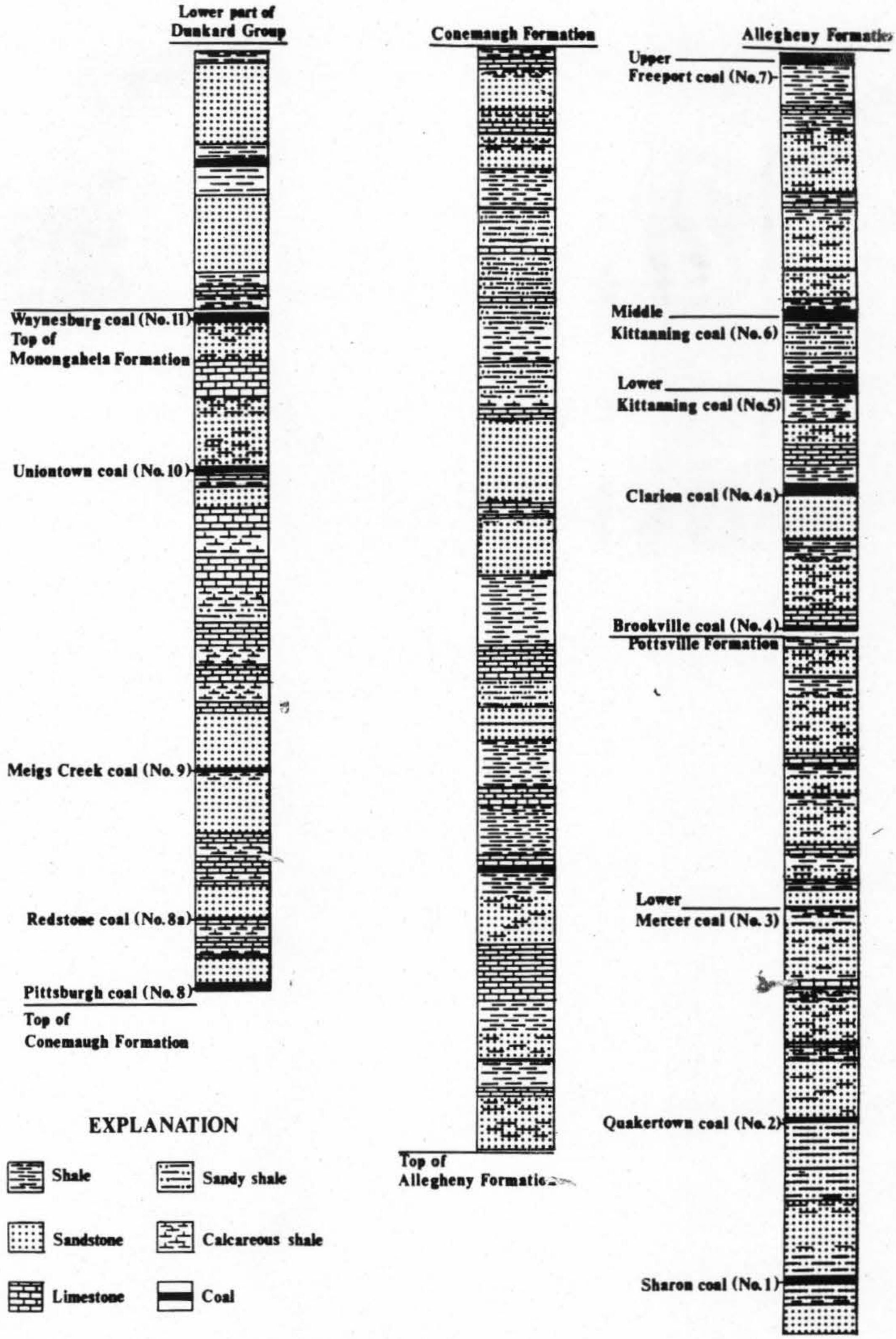

Figure 4. Generalized Stratigraphic sections of the Pennsylvanian and Permian Formations in Ohio. (from Pfaff et al, 1981)

existed, and drainage from surface mines added to acid drainage problems (Pfaff et al, 1981, p.3). Reclamation laws that were developed were poorly managed, and many mining areas went unreclaimed. Finally, in 1972, a second law was passed (section 1513.16 of Ohio revised code, Ohio strip mine law), which established more stringent reclamation requirements, more expensive reclamation bonds, and penalties for failure to reclaim (Pfaff et al, 1981, p.3).

In surface mining, all of the overlying sediment must be removed. The sediment is scraped away, and then transported to a designated area, where it is deposited in spoil piles. The spoil bank resulting from strip or open pit mining is a heterogenous mass of earth that has physical and chemical properties determined by the rock strata overlying the coal (Cummins, Plass, and Gentry, 1965, p.1). This material is unique, bearing little resemblance to the original overburden and soil, and it sometimes poses difficulties to those attempting revegetation (Cummins, Plass, and Gentry, 1965, p.1). Understanding the chemical and physical properties of spoil piles is important in determining their effect on the environment.

In a report entitled Chemical and Physical Properties of Spoil Banks in the Eastern Kentucky Coal Fields, Cummins, Plass, and Gentry (1965) studied sedimentary overburden dating from the Pennsylvanian period. The results they found are:

> Spoil samples from the coal seams were medium to extremely acidic with low concentrations of total

soluble salts and organic matter. Spoil banks are a mixture of rock fragments (composed of various minerals) ranging in size from massive chunks to sand silt, and clay. The pH of the spoil banks ranged from 2.2 to 5.7. Generally, as the pH decreases below 4.5, toxic ions come into solution and some essential nutrients become less available to plants (Cummins, Plass, and Gentry, 1965, p.1-3).

One of the main problems pertaining to the spoil piles at the headwaters of The West Bank Shade River, is acid mine drainage, which is produced by the oxidation of iron sulfides present. The iron sulfides present are pyrite and marcasite (FeS_2). These minerals [pyrite and marcasite] are disseminated in varying amounts throughout the coal bearing formations, especially in sandstones associated with and overlying the coals (Pfaff et al, 1981, p.5). Strip mining exposes the pyrite and marcasite to air and water by increasing the surface area exposed to the elements. The oxidation of pyrite involves several reactions (Pfaff et al, 1981, p.5-9):

$$(1)\,FeS_2\,(s)+7/2O_2+H_2O \rightleftharpoons Fe^{2+}+2SO_4^{2-}+2H^+$$

$$(2)\,Fe^{2+}+1/4O_2+H^+ \rightleftharpoons Fe^{3+}+1/2H_2O$$

$$(3)\,Fe^{3+}+3H_2O \rightleftharpoons Fe(OH)_3(s)+3H^+$$

$$(4)\,FeS_2(s)+14Fe^{3+}+8H_2O \rightleftharpoons 15Fe^{2+}+2SO_4^{-2}+16H^+$$

In the reactions 1, 3, and 4, hydronium ions are produced, which will increase the acidity. Many other factors are important in determining the amount of acid mine drainage that occurs. Grain size, shape, and arrangement of particles has a direct effect on porosity. Materials that have a high porosity or permeability will allow more water to reach the sulfides, increasing oxidation. The spoil piles also impact the environment by becoming a source of sediment.

The placement of the spoil piles at the headwaters of The West Branch Shade River, along with the presence of highwalls, provided a major sediment source. The low pH values of the spoil prevent revegetation of the spoil banks. Erosion of the spoil piles caused by precipitation and overland runoff provided a direct sediment source. In some areas, up to two meters of sand derived from the spoil piles have been deposited in the river and adjacent flood plane. The result of the vast sediment loading is a river that has exceeded its capacity. As the rivers capacity decreased, so did the channel conveyance. Channel conveyance is a measure of the carrying capacity within a channel and has dimensions of cubic feet per second (Darlymple and Benson, 1968, p.28). As The West Branch Shade River lost its ability to carry sediments downstream, the sediment was then dropped in the channel in the form of islands and bars. This caused The West Branch Shade River to change its fluvial system. The West Branch Shade River, which was a meandering fluvial system, was transformed into a braided fluvial system (J. Havasi, 1994, peers. comm.). A table describing the relationship between sediment load and type of alluvial channel can be seen in figure 6 (Selby 1985, p.269).

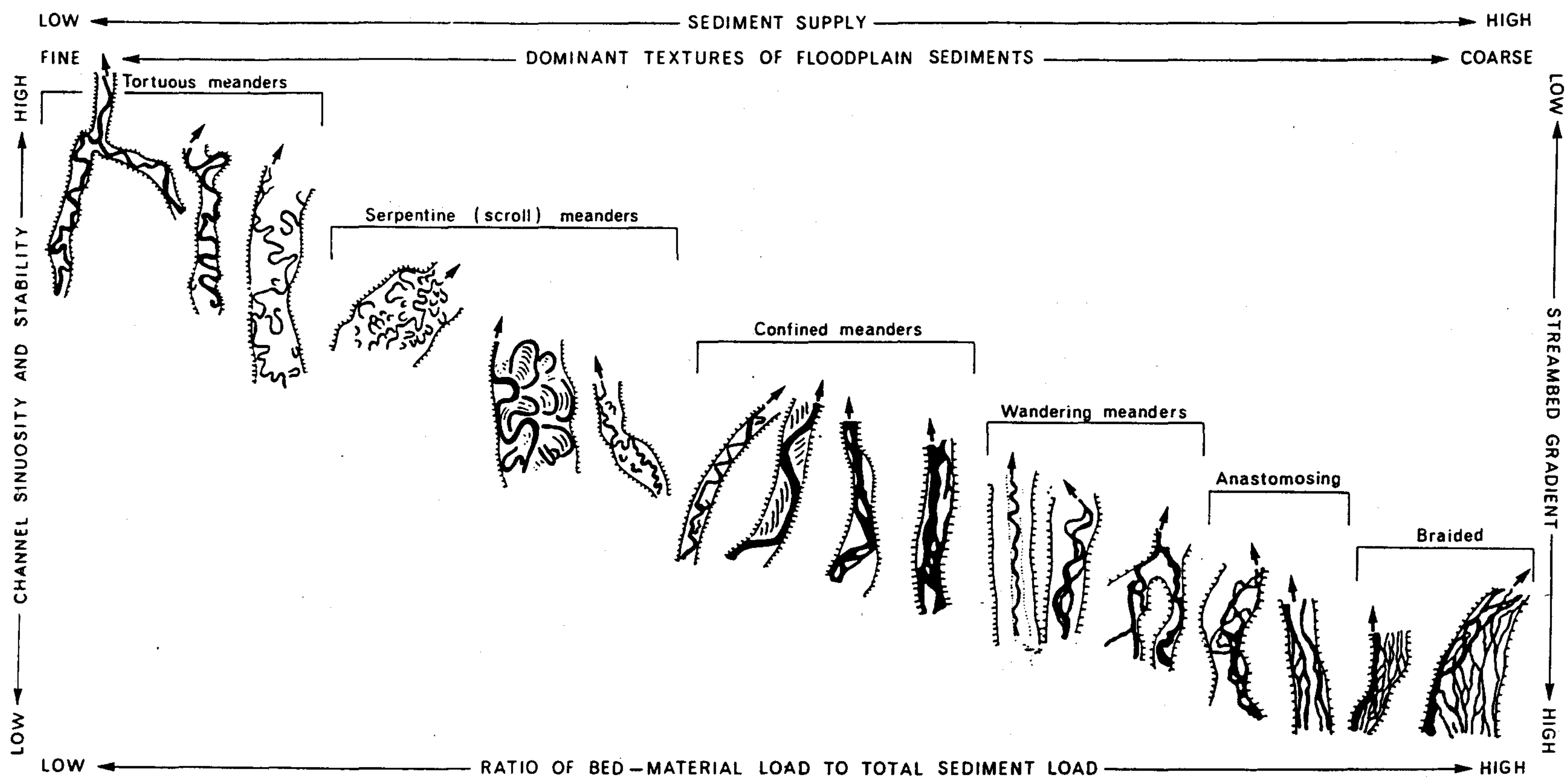

Figure 5. The relationships between the form and slope of alluvial channels and the supply, texture, and type of sediment load. (from Shelby, 1985.)

"The chief characteristics which are identified as being the cause of braiding are (1) overloading which caused the stream to deposit part of its load; (2) steep slopes which provide a wide shallow channel in which bars and islands form readily; (3)easily eroded banks which permit the channel to be widened at increased flow; (4) large bed material in comparison to suspended load so the large material is immovable except at flood stages (Shelby, 1985, p.277)." Each one of these characteristics could be used to describe The West Branch Shade River at the time of reclamation. The sediment loading, which caused the channel to change its fluvial system, was also a major cause of flooding.

The major agricultural effect that is evident in these areas of flooding, is the spread of this acidic sediment over fertile farmland. During periods of heavy precipitation and peak flow, the overloaded stream beds could not hold the excess water supply, and the land was flooded. Many of the roads and bridges in the area were raised in order to avoid the problem of frequent flooding. The overall environmental problem finally reached a point where legislation was amended to allow for proper reclamation of the area.

METHODS OF STUDY

Two stations were set up on the West Branch River. Station one is located downstream, near Snowville, about 1/4 of a mile off route 681 (figure 2). Station two is located west of station one, near the headwaters of the West Branch River. Station two is positioned about 10 meters north off a bridge, where the river crosses route 681, near Harrisonville. Data collection took place in 29 October 1994. I was asserted in the field by Joe Havasi, who graciously invited me to undertake this study in his thesis area.

Walking to station one, visual observances were made on channel conveyance, river capacity, and channel width. Also noted were characteristics of the river for purposes of classification.

Specific conductance measurements were made at both stations using a conductivity meter. Water samples were taken in a beaker; readings were taken based on water temperature at that time. Specific Conductance is measured by passing a current between two electrodes that are completely submerged in the water being measured. pH was measured by the use of litmus paper.

In the section of the stream bed that was still covered with water, a record was made of how much sediment still overlaid the original silty clay layer. Which was interpreted as the former bed of this meandering stream. These measurements were made by burrowing a hollow plastic tube into the stream bed. Then, by sealing off the top of the tube, a small core section could be made of the river bottom. At station two, an extra core was taken from a point bar, that was above the water.

Channel cross sections were also measured at the two stations. The cross sections were measured using a jacobs staff, a transit, and a tape measure. For station one, measurements were made in a river bend over the formation of a point bar. The transit was set up in the river, and measurements of elevation of river bottom were made every five feet. The cross section was completed by combining the information collected from the transit readings and the core sections described above. Station two was selected where the flow was relatively straight. The cross section was made by placing the transit on a nearby bridge, 10.5 meters away. Measurements were taken every five feet from one side of the stream to the other.

SAMPLING RESULTS

As I walked through the stream to go to station one, the first thing I noticed was how much sand was present in the stream bed. Small islands and bars were still present above the water, showing signs of a braided stream. I also noticed that the stream also showed signs of a meandering system. The type of system the West Branch Shade River is at station one, would have to be a braided, meandering system. The stream showed characteristics of both systems.

The width of the stream ranged from 1 to 4.5 meters. The depth of the stream varied from 2 centimeters to 1.3 meters, in the turns of a meander. The river banks that were present on each side reached heights above my head at times. This gave me an impression that the capacity of the river had increased compared to what I had read in the 1985 report.

Core tests were taken at different points of the stream bed at station one. Each test yielded the same result, the sand depth in the channel was approximately 10 inches. The sand is described as sub angular, poorly sorted, coarse to gravel size

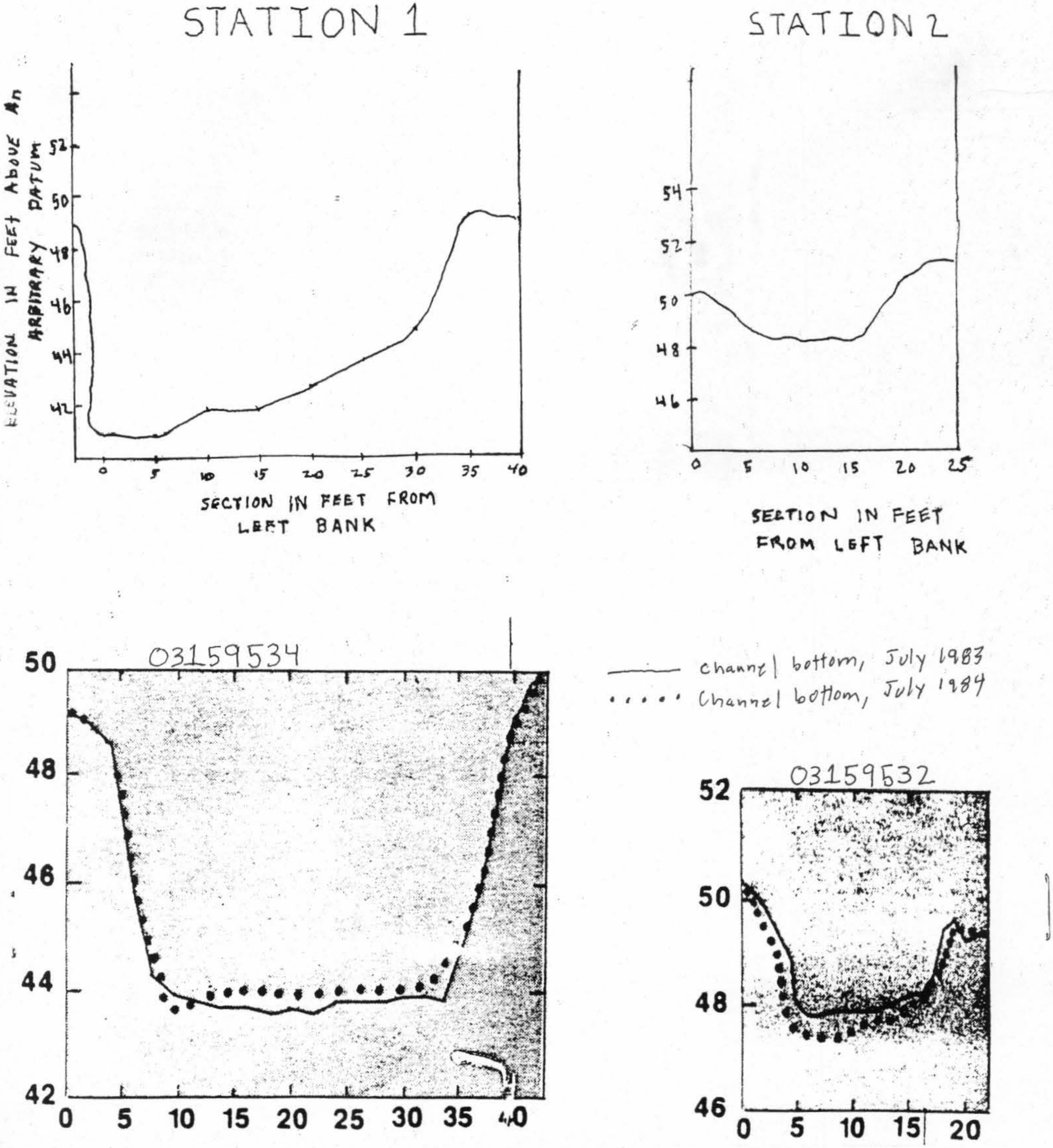

Figure 6. Top: Cross sections from the 1994 report
Bottom: Corollating cross sections from the 1985 report

(from Childress and Jones, 1985)

brown sand with organics. The organics were mainly in the form of coal fragments that were scattered throughout the sand. The core showed that the sand made a distinct boundary with the clay layer that lies below. All the sand that made up the point bar can be classified under the same description as given above.

A number of conductivity measurements were taken to get an accurate reading. Results from the 1985 study, compared to the results gathered in 1994, are shown in tables 2 and 3. The cross section for station one is illustrated in figure 6, along with the cross section from the 1985 report for comparison. The distance to the bottom of the channel for the 1994 cross section, compared to the 1985 cross section, shows that a considerable amount of sand has been washed downstream.

At station two, the channel width varied from .3 to 1.5 meters wide. The channel had sand built up in the form of bars and islands. The stream had the characteristics of a braided fluvial system. In many areas where water was present gas or oil was floating on top of the water.

The core test at station two was taken from the stream bottom, was found to contain 7.5 centimeters of sand to the clay layer below. The core sample taken from the point bar was found to contain 4 centimeters of sand to the clay layer. The sand can be described is the same as at station one. The only difference being that the sand at station two contains some grains that are coarser. This may be a result of station two being closer to the sediment source. The core samples also have distinct boundaries

Station #	Specific Conductance($\mu S/cm$)	pH	Water Temp.°C
1	420, 440, 435 440, 438, 440 Ave 435.5	6.1	13
2	570, 565, 560 575, 560, 565 Ave 565	4.9	14

Table 1: Water Quality Analysis of Samples Collected 10/29/94

Table 2 -Water-quality analyses of samples collected at each of the gaging stations--Continued

03159534 -- West Branch Shade River near Burlingham, Ohio

Date	Time	Temperature (°C)	Streamflow, instantaneous ft^3/s	Specific conductance (µS/cm)	pH	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Iron, suspended recoverable (µg/L as Fe)	Iron, total recoverable (µg/L as Fe)
Jan. 16, 1984	1200	0.5	6.7	455	5.8	18	200	200	1400
May 22, 1984	1450	24.5	5.4	411	6.7	30	170	--	670
June 27, 1984	1115	--	--	--	--	--	--	--	--

Date	Time	Iron, dissolved (µg/L as Fe)	Maganese, suspended recoverable (µg/L as Mn)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Aluminum, total recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Aluminum, suspended recoverable (µg/L as Al)	Acidity (mg/L as H)	Drainage area (mi^2)
Jan 16, 1984	1200	1200	0	3300	3300	1000	100	--	0.1	22.2
May 21, 1984	1450	670	650	--	2200	400	100	--	.1	22.2
June 27, 1984	1115	--	--	--	--	--	--	--	--	22.2

(from Childress and Jones, 1985)

between the sand and clay layers.

SUMMARY AND CONCLUSIONS

By comparing the results produced from the report made in 1994, to the report made in 1984, approximately 0.3 to 0.9 meters of sediments have been removed from the channel bed. Specific conductance shows levels that are similar to the values measured in the 1985 report. The same is true for pH levels measured. The fluvial system is showing signs of a meandering system as you go farther downstream. Overall, I feel that the reclamation efforts are working, due to the amount of sand that has been removed. The stream is starting to regain its old shape.

ACKNOWLEDGEMENTS

I would like to thank Dr. Mckenzie for advising me for this thesis report, and the use of his conductivity meter. Also, I would like to give a big thanks to Joe Havasi, graduate student in geological sciences, for introducing this project to me, providing transportation, and assisting me in the field.

Table 3. --Water-quality analyses of samples collected at each of the gaging stations

03159532 -- West Branch Shade River near Harrisonville, Ohio

Date	Time	Temperature (°C)	Streamflow, instantaneous ft^3/s	Specific conductance (µS/cm)	pH	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as as SO_4)	Iron, suspended recoverable (µg/L as Fe)	Iron, total recoverable (µg/L as Fe)
Jan. 16, 1984	1600	0.0	0.33	560	5.1	3	300	900	2900
May 22, 1984	0800	16.5	.20	572	4.1	--	290	--	1400

Date	Time	Iron, dis-olved (µg/L as Fe)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Aluminum, total recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Aluminum, suspended recoverable (µg/L as Al)	Acidity (mg/L as H)	Drainage area (mi^2)
Jan. 16, 1984	1600	2000	0	5800	5800	7000	6900	100	1.9	0.99
May 22, 1984	0800	30	--	5300	5200	4600	4300	--	1.0	.99

(from Childress and Jones, 1985)

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